bases of becoming aware of experience, abstracting relations, producing correlates, the volitional control of mental process, or the intimate and immediate awareness of self.

The physiological phenomena, like the physical ones, do not contain the principles of their own explanation within themselves. When we examine the segmentation of a cell under a microscope, we conceive of it as a process going on in an existent, material and unitary thing. Whence do these concepts of existence, matter, unity and thinghood come ? When we stimulate the nerve of a nerve-muscle preparation and notice a contraction of the muscle, we conceive of the event as a causal one. Whence did we derive our notion of cause ? When we measure the intake and output of a living organism, we do so in terms of energy. From what experience is that concept of energy taken ? The ground of none of these concepts is to be found in any one, nor in the sum total of observations made. All these and like beliefs are inferences from the phenomena, made in virtue of experiences of another kind. Physiology, accordingly, like physics, is an empirical science in the first sense because it concerns itself with certain selected sensory data; in so far as it is explanatory, it is an inferential science. It is none the worse for that, however, even if it must borrow some of its concepts from psychology. The point is that, generally without acknowledgment, it does so borrow from psychology in order to establish the very constructions it offers to reloan to that science as explanations of mental events.

*(To be continued.)*

## Progress in Electrical Communication

IT is becoming almost commonplace to remark that the growth of modern civilisation has been dependent to a very considerable extent upon the progress made in the art of communication, and, in particular, upon the facilities provided by electrical communications in linking together portions of the earth geographically remote from one another. The British Empire, with its widely distributed interests, has special need of efficient long-distance communication, and it is perhaps, therefore, significant to recall how large a part Great Britain has played in the development of that special branch of science which has nowadays earned the title of "communications engineering".

On the occasion of the ninth annual Norman Lockyer lecture of the British Science Guild, delivered on Thursday, November 23, Prof. E. V. Appleton gave a discourse on "Empire Communication" in which he outlined the growth and development of both wire and wireless communication as employed to meet Imperial needs (British Science Guild, 6 John Street, Adelphi, London, W.C.2. 1*s*.). At the beginning of the lecture, the audience was reminded that the first two great pioneer achievements in long-distance communication were concerned with the linkage of Great Britain with her oldest colony, Newfoundland. For, in August 1858, cable communication was first established between Valencia in Ireland and Trinity Bay, Newfoundland ; while in December 1901, Marconi's signals from Poldhu, in Cornwall, were successfully received across the Atlantic by means of a kite-aerial at Signal Hill, also in Newfoundland. In this manner was demonstrated the potentialities of the two methods of electrical communication, one making use of an electric current guided along a copper conductor, while the other utilises the propagation of free electric waves. In spite of the intense controversy which has at times taken place on the relative advantages of communication by submarine cable and by wireless transmission, experience has shown generally that each system, in its own particular sphere, supplements rather than competes with the other.

### EMPIRE CABLE SERVICES

With its advantageous start of nearly half a century, it is natural to find that the submarine cable had practically interlinked all parts of the British Empire by the time that wireless communication was able to offer a practicable alternative. Following the laying of several Atlantic submarine cables, similar links were established between England and India, Australia, New Zealand and all parts of Africa, in the development of Imperial communication. More than half the world's long-distance cables now forms part of the great British merger known as Cables and Wireless, Ltd. (the holding company), and Imperial and International Communications, Ltd. (the operating company).

Lord Kelvin was responsible for initiating the electrical methods and many of the instruments used in submarine cable telegraphy ; and essentially the same basic principles, of course with vastly improved technique, are still employed to-day. In the early days, sending was done with a special form of Morse key, whereas to-day automatic methods are employed at both ends for the transmission and reception of messages. Much of this terminal equipment is, of course, equally adaptable to wireless telegraphy stations, and in this sense the younger branch of the communication family has benefited by the experience and technique developed by its senior members.

After it was thought that the speed of signalling, and thus the message-carrying capacity, of the submarine cable had reached a limiting value, the development of high permeability nickel-iron alloys opened up further possibilities which have been rapidly exploited. The Western Electric Co. of America produced the first experimental continuously-loaded cable, in which permalloy was wrapped round the core of the cable in the form of a thin narrow ribbon. Another alloy, called mu-metal, due to the Telegraph Construction and Maintenance Company, also became available for application to the copper cable core in the form of a continuous single-layer winding of thin wire. The fundamental principles of this form of loaded cables were first enunciated by Oliver Heaviside, and by application in the manner described, cable engineers have been enabled to increase the traffic-carrying capacity of many sections of the Empire cable routes to about ten times their former value. As an example, given in the lecture, the latest cable to link up Newfoundland with the Azores is stated to be capable of working at a speed of 340 words per minute in each direction simultaneously.

### Empire Wireless Services

Prof. Appleton then outlined very briefly the growth of communication by wireless telegraphy from the early trans-Atlantic experiments referred to above. In the course of this work, most of which was of an empirical nature, it was found that, for long-distance communication, wave-lengths in the range 1,000-20,000 metres were required, and until about 1920, wave-lengths less than 1,000 metres and down to about 200 metres were restricted to the use of mobile services, such as ship communication. The introduction of the thermionic valve provided, amongst other things, an easy means for generating oscillations at wave-lengths well below 200 metres, and the first indication of the extraordinary possibilities of short-waves for long-distance communication came from the experiments of amateurs in December 1921. From this time the progress made by amateurs' experiments in signalling between different parts of the Empire on wave-lengths of less than 200 metres was very rapid, and it culminated in October 1924 with the establishment of communication between F. Bell in New Zealand and C. W. Goyder, a schoolboy at Mill Hill, near London. It has since become very clear, however, that much remained to be done in the way of development of technique and acquiring of knowledge and experience, before these short wave-lengths could be utilised for reliable commercial communications.

In March 1923, the British Government decided to erect, in the interests of national security, a large wireless station capable of communicating with the Dominions. The Post Office prepared to erect this station at Rugby, as well as to consider a proposal from the American Telegraph and Telephone Company for connecting the telephone system of America with that of Great Britain by means of a wireless telephone link. By the end of 1926, both these services were in successful operation on long wave-lengths.

Concurrently, the Marconi Company was busily developing the technique of short wave transmission and reception, and the work of C. S. Franklin is notable in the adaptation of aerial array and reflector systems for the production of directed beams for point-to-point communication. By the end of 1927, four short-wave beam stations were completed by the Marconi Company for the Post Office for communication with Canada, Australia, South Africa and India. These stations have proved very successful and are capable of traffic speeds of 300 words per minute.

Following upon these stations, the Post Office has established wireless telephony services in recent years between Great Britain and different parts of the Empire. The beam sending stations for this purpose have been built at Rugby, while the corresponding directional receiving stations are installed at Baldock, both being controlled from a telephone exchange in London. These short-wave links, in conjunction with the long-wave trans-Atlantic telephone service mentioned above, have been developed of recent years to such an extent that London has become literally the world's switching centre for the majority of long-distance telephone conversations between all continents.

Passing from the application of wireless telephony for the private use of ordinary telephone subscribers, it is natural to inquire as to its possibilities for long distance broadcasting purposes, and here Prof. Appleton recalled that on December 19 of last year, the first series of Empire broadcasts for overseas listeners was inaugurated. Utilising all the experience obtained in the other applications of short-wave beam systems, two sending stations were installed at Daventry with a series of different aerial systems to direct the beam in the appropriate direction for the benefit of the distant listeners. The first year of this Empire broadcasting is drawing to a close, and with the aid of more than 10,000 reports of reception in various parts of the world, it is expected that both the technical and programme sides of this service may be improved, although, with some exceptions, these may already be considered to be fairly satisfactory in view of the various difficulties which had to be encountered.

### Solar Activity and Wireless Transmission

It is nowadays quite adequately established that long-distance wireless communication is only brought about by the reflection or refraction of the waves in passing through the electrified regions of the upper atmosphere, now generally known as the ionosphere. In making a wireless journey around the earth, the waves are reflected alternately by the ionosphere and the ground. Modern research on this phase of wireless communication, to which Prof. Appleton has himself been a notable contributor, has shown that the electrification in the upper atmosphere is not by any means constant. It is usually denser by day than by night, and denser in summer than in winter, facts which indicate quite definitely that the electrification is controlled by the sun. It is now known that there are two main regions of intense electrification in the upper atmosphere, and that long waves are reflected at the lower of these, while short waves are reflected at the upper region.

The shortest wave-length that can be reflected depends on, amongst other things, the density of electrification; and there is therefore a lower limit to the wave-lengths which may be used for long distance communication. The limiting wave-lengths which penetrate the ionosphere without return to earth vary from somewhat less than 10 metres for a summer noon to 23 metres for a winter night.

Since the propagation of waves to long distances is so dependent upon the state of electrification of the upper atmosphere, any variations in this electrification produce variability in the wave transmission, and as experience shows, the effect is more marked with short than with long waves. The electrification of the ionosphere is not only subject to diurnal and seasonal variations; it is also profoundly affected by changes in solar activity, with its accompanying production of magnetic storms and auroral displays. Much speculation has taken place as to the means by which the appearance of a group of sunspots influences the earth's magnetic field and produces auroræ. On one hand, Birkeland and Størmer, the Norwegian investigators, have suggested that streams of electrified particles are shot with great speed from the sun and, on reaching the earth's atmosphere, give rise to intense circulating currents resulting in the effects observed. The tracks of the charged particles will be influenced by the earth's magnetic field so as to intensify the magnetic and auroral phenomena in polar regions. Within the last few years, however, Maris and Hulbert, rejecting the corpuscular theory, have suggested that all the observed effects may be due to the arrival in the upper atmosphere of intense ultra-violet radiation emitted from abnormally hot spots on the sun's surface.

Whatever may be the means by which the occurrence of solar activity is conveyed to the earth, there is little doubt as to the effects observed. The electrical currents circulating in the upper atmosphere induce corresponding currents in the earth, and these in turn affect cable communication, which is always worked with an earth return circuit. Although cable engineers have devised methods of mitigating the influence of these spurious signals, there are still occasions, particularly in years of sunspot maximum, when the effects are so strong and variable that many services are put out of action. In wireless transmission, the influence of solar activity is even more marked, particularly on the shorter wave-lengths. The result is almost always to produce an increased absorption of the waves during their passage through the atmosphere, which may be sufficient to interrupt communication completely for days at a time. In view of the comparatively immature state of short-wave technique, there is little doubt that, as a result of the research now being vigorously pursued by both the physicist and the communications engineer, considerable improvement in long-distance communication will accompany more complete knowledge of the relations between the sun and the earth.

## The Baffin Bay Earthquake

A GREAT earthquake was recorded on the night of November 20 at West Bromwich, Kew and other observatories. The first tremors reached Kew at 11h. 38m. 24s., p.m., and the disturbance registered there was of an intensity that is reached only about ten times a year. The record shows that the epicentre lay about 2,400 miles north-north-west of Kew, in Baffin Bay, and this determination is supported by records at Bombay (distant 5,700 miles) and in the Canadian observatories.

The interest of the earthquake lies in the fact that it occurred in a district hitherto supposed to be free from earthquakes, and this has led to the suggestion that the shock may have been caused by the fall of an unusually large meteorite. There is nothing improbable in this, for the impact of the great Siberian meteorite of June 30, 1908, produced waves that were recorded, though feebly, at Jena, distant 3,250 miles (Dr. F. J. W. Whipple, *Quart. J. Roy. Met. Soc.*, **56**, 287–301; 1930). On the other hand, the movement registered at Kew was of great magnitude, and there seem to have been no remarkable air-waves such as were recorded in 1908 by barographs in British observatories.

The recent earthquake has directed attention to the rarity of earthquakes in the polar regions. It thus seems desirable to obtain some estimate of the distribution of earthquakes in relation to latitude. The only records that are of service for this purpose are those provided by seismographs. Taking the shocks contained in the valuable "Catalogue of Earthquakes 1918–1924" edited by the late Prof. H. H. Turner (Brit. Ass. Rep., 1928, pp. 214–304) and representing by 100 the number of earthquakes in the zone between 0° and 10° N. lat., the numbers occurring within equal areas in the zones bounded by successive parallels of 10° N. lat. are 100, 430, 512, 1770, 1541, 532, 130, 164 and 145. For the southern hemisphere, the corresponding figures are 413, 403, 234, 142, 87, 78, 20, 17 and 0. The large numbers for the mid north temperate zones are no doubt due chiefly to the close distribution of seismographs.

Confining ourselves to earthquakes registered more than 80° from their origins, the corresponding numbers for the northern hemisphere are 100, 77, 81, 108, 129, 136, 4, 19 and 0, and for the southern hemisphere 93, 72, 48, 41, 22, 19, 0, 5 and 0. These figures thus point to a somewhat higher seismicity in the zones between 30° and 60° N. lat., while in the southern hemisphere they show a nearly regular decline southwards. Moreover, the occurrence in both polar zones of great earthquakes like that of November 20 is clearly most unusual.